OFFSET BASED LEAKY PREDICTION FOR ERROR RESILIENT ROI CODING

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ABSTRACT

During the period of transmission, video data usually suffer from transmission errors inevitably. Intra update is a common approach to stop error propagation. However, damaged images cannot recover until next update in case of errors, which often leads to annoying effect. In this paper, we propose an enhanced leaky prediction approach that enables the Region-Of-Interest (ROI) of images to recover gently from the immediate succeeding frame of erroneous ones in favor of better human perception. Moreover, an optimized offset compensation technique is designed to improve coding performance. Experimental results show that the proposed scheme can achieve better image quality for ROI and the fluctuation of bitrate is greatly reduced, compared to the intra update method.

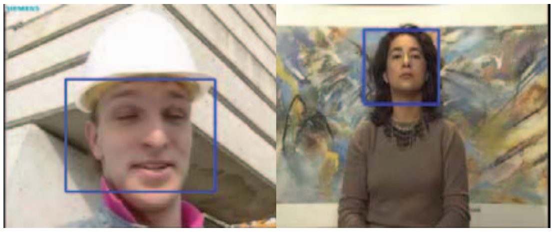
Index Terms— error resilient, ROI, leaky prediction, offset compensation, H.264/AVC

1. INTRODUCTION

With the rapid development of multimedia technologies, there is an increasing demand for video transmission nowadays. However, common underlying channels, such as the Internet or wireless networks, usually provide only best-effort services. Thereby video data often suffer from transmission errors inevitably.

Research on Human Visual System (HVS) reveals that people generally pay more attention to the Region-Of-Interest (ROI) areas, such as the heads in fig. 1. So in order to achieve better visual quality, ROIs should be treated specially. As video frames are usually inter-frame coded, error propagation in ROI areas has to be properly dealt with. Error concealment can repair erroneous areas of images using temporal or spatial neighboring ones. But such recovery is limited for ROI areas with complex motion and textures. Thus, other error resilience tools are still desired.

Some schemes are proposed to enhance the robustness of ROI areas against errors at the source encoder level. For example, [1] employs a nonlinear transform in ROI areas during pre- and post-processing, and [2] performs double motion estimation for ROIs. Besides, some research works [3~5] choose to combine the resilience feature of source encoder, such as Flexible Macroblock Ordering (FMO) tools, with transport level protection like Forward Error Correction (FEC). With these methods, Unequal Error Protection (UEP) can be applied to provide more protection to ROI areas than backgrounds during transmission.


(a) (b)
Fig. 1 ROI from (a) “Foreman”, (b) “Silent”.

In this paper, we contribute another effective source level error resilient tool for enhancing the error robustness of ROI without sacrificing much coding efficiency. Our scheme designs a special weighted prediction approach for ROI areas. On one hand, leaky prediction technique is adopted to ensure erroneous regions recover gradually with time. On the other hand, an optimized offset compensation can effectively prevent rate-distortion performance from dropping and keep the constant quality of ROI when no error happens. Furthermore, this scheme also reduces fluctuation of bitrate significantly, which is friendly to packetization or FEC processing at the transport layer. It should be noted that our scheme needs no changes to the H.264/AVC standard [6] and can be easily implemented by existing weighted prediction tools.

The remainder of this paper is organized as follows. In Section 2, the proposed scheme and its implementation are described in detail. Experimental results validating the effectiveness of our scheme are shown in Section 3. Section 4 draws the conclusion.

2. OFFSET BASED LEAKY PREDICTION

Considering ROIs usually don’t take up too much space of the whole image, an intuitive method of stopping error propagation is periodical intra-update of ROI. However, such method often incurs annoying visual perception at low frame rate scenarios such as the mobile video phone, since quality of ROI may be always poor until the next intra-update. Another gentle way to combat error propagation is the classical leaky prediction, which we will investigate and improve in the following subsections.

2.1. Mechanism of Offset-based Leaky Prediction

Suppose leaky prediction is applied to signal f with reference p, and the resultant prediction residual is

$$r = f - \alpha p . \tag{1}$$

Since leaky factor α is less than 1, the downside of leaky prediction is increased prediction residual. As for ROI based resilient coding, we can constrain leaky prediction specific to ROI slices during encoding to mitigate this disadvantage. Let $I(i)$ be the pixel value of current ROI and $I_p(i-1)$ be that of the reference image. As for inter coding, residual of the classical leaky prediction is calculated by

$$R(i) = I(i) - \mathrm{MC}\left(\alpha_i I_p(i-1)\right), \tag{2}$$

where α_i is the leaky factor for current ROI, and MC means "motion compensation". As we know, ROIs usually change little between neighboring frames and often exhibit uniform characteristics. Leaky prediction in (2) introduces extra bias. As such bias or DC component is vitally important and usually consumes many bits during coding, decent compensation is desired. We can introduce a suitable offset value d_i to compensate this bias. Then the prediction residual becomes

$$R^{'}(i) = I(i) - \mathrm{MC}\left(\alpha_i I_p(i-1)\right) - d_i . \tag{3}$$

Thus the resulting bitrate is expected to decrease naturally.

We can further see this offset-based leaky prediction still keeps the property of error convergence with time. Suppose an error e happens in the reference of current ROI areas, which accordingly yields the prediction

$$\mathrm{MC}\left(\alpha_i \left(I_p(i-1) + e\right)\right) + d_i . \tag{4}$$

Assume motion compensation simply performs direct frame copy operations. Then after n frames, it's easy to find effect of errors will attenuate to be

$$\prod_{i=1}^{n} \alpha_i e \to 0 \tag{5}$$

approximately.

2.2. Determination of Leaky Factor and Offset

Similar to the ROI-specific intra-update scenario where ROI areas are intra coded every other n frames, we hope to stop errors as fast as possible. Inspired by the half-life concept in [7], leaky factor α_i is derived based on the expectation that errors will decay by $1/2$ after n frames approximately:

$$\prod_{i=1}^{n} \alpha_i = 1/2 . \tag{6}$$

Although we can adaptively adjust α_i for different frames under the constraint (6), we set α_i to be $\sqrt[n]{1/2}$ equally for simplicity.

As for the offset value d_i, we derive it by

$$\begin{aligned} d_i &= \arg\min_{d_i} \left\| R^{'}(i) \right\|_2 \\ &= \arg\min_{d_i} \left\| I(i) - \mathrm{MC}\left(\alpha I_p(i-1)\right) - d_i \right\|_2 \end{aligned} . \tag{7}$$

For simplicity of analysis, direct frame copy is assumed for motion compensation here. Then it's easy to get

$$d_i = \overline{I(i)} - \alpha \overline{I_p(i-1)}, \tag{8}$$

where $\overline{I(i)}$ and $\overline{I_p(i-1)}$ are the average pixel value of ROI in the current and the reference frame respectively.

2.3. Implementation issues

In H.264/AVC, weighted prediction is originally introduced to encode fading sequences. According to the above analysis our offset-based leaky prediction can be seen as a special case of weighted prediction. So weighted prediction tools can also be employed to implement the proposed scheme. Besides, FMO can be used to divide images into ROI and background slices. As weighted prediction in H.264/AVC is slice-independent, ROI-specific leaky prediction can be easily implemented.

In our scheme the whole ROI slice of a frame shares the same offset value, which can be regarded as additive offset of the slice layer syntax in H.264/AVC. We can make use of the related *luma_offset* and *chroma_offset* fields, which can indicate the offset value, i.e. the DC compensation value, for each color component of ROI slices.

Therefore, our proposed ROI-specific leaky prediction scheme with offset compensation can be totally incorporated into the existing H.264/AVC standard. And effectiveness of the proposed scheme is shown in the following section.

3. EXPERIMENTAL RESULTS

Now the proposed scheme is evaluated for the first 50 frames of two standard CIF sequences "Foreman" and "Silent". As this paper doesn't focus on object extraction, ROIs are simply designated as in fig. 1 and are supposed not to change. In experiments, ROI-specific intra-update and the proposed ROI-specific leaky prediction are compared. Suppose ROI slices are intra-updated every other 5 frames, i.e. in the 6th, 11th, 16th, … frames for the ROI-specific intra-update scenario, which is determined for illustration purpose. And with half-life set to be also 5 frame periods, the leaky factor $\sqrt[5]{1/2} \approx 27/32$ is applied as in section 2.2 for our proposed scheme in experiments.

In the following, JM 14.2 [8] is modified to support our experiments. And images are separated into ROI and background slices. Except the first IDR frame, all the remaining frames are coded as P-frames. One reference frame is used during encoding, and search range of motion estimation is set to 64 pixels. In ROI-specific intra-update scenario, both ROI and background slices use the same QP=28. But in ROI-specific leaky prediction, QP of ROI slices in the other 49 P-frames is set to be 28 while background slices use QP=30, except the first IDR frame, in which QP=28 is always used. All the configurations are determined for fair comparison thereafter.

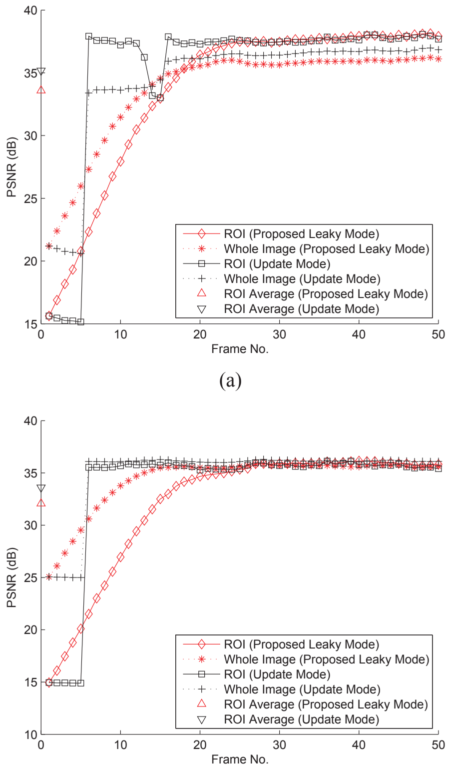
In experiments, error concealment of frame copy is used at the decoder side if necessary. And ROI-specific intra-update and the proposed offset-based leaky prediction are called update mode and leaky mode respectively for short in the following.

3.1. Error Resilience Performance

With encoding configurations stated above, update and leaky modes produce nearly the same average bitrate. Let's first consider the case that the ROI slice of the first IDR frame is lost. The PSNR of every frame for two sequences "Foreman" and "Silent" is shown in fig. 2. From experimental results we can see that in the update mode, quality of ROI cannot improve until the next ROI-specific intra-update. But in the leaky mode, quality of ROI can recover gently starting from the very succeeding frame. Though the average PSNR of ROI in the leaky mode is less than that in the update mode, PSNR value sometimes cannot adequately indicates the subjective visual quality. ROIs of the first 5 frames for "Silent" are shown in fig. 3. Information of the ROIs nearly is lost totally with ROI-specific intra-update. But part information of the ROIs can still be obtained from the 2nd frame with ROI-specific leaky prediction, which generally presents better visual quality, especially for applications of low frame rate.

Next, let's see the experimental results when the 6th frame is lost, as shown in fig. 4. Now the average PSNR of ROI with ROI-specific leaky prediction is close to that with ROI-specific intra-update. Update mode still shows abruptness and fluctuation of quality in ROI areas such as the case from the 10th to the 20th frame in fig. 4(a). But quality of ROI can recover gently and monotonically with ROI-specific leaky prediction.

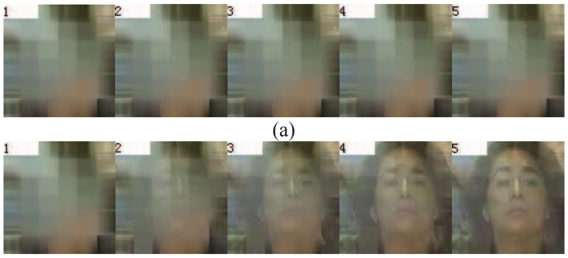
In fact, except for the first IDR frame, in the leaky mode loss of some other frame usually gives similar results as the loss of the 6th frame according to experimental results. Quality of ROI always improves gently and monotonically in case of errors, which is usually preferred by human perception.



(a)

(b)

Fig. 2 Image quality of every frame when ROI slice of the first IDR frame is lost (a) "Foreman", (b) "Silent".



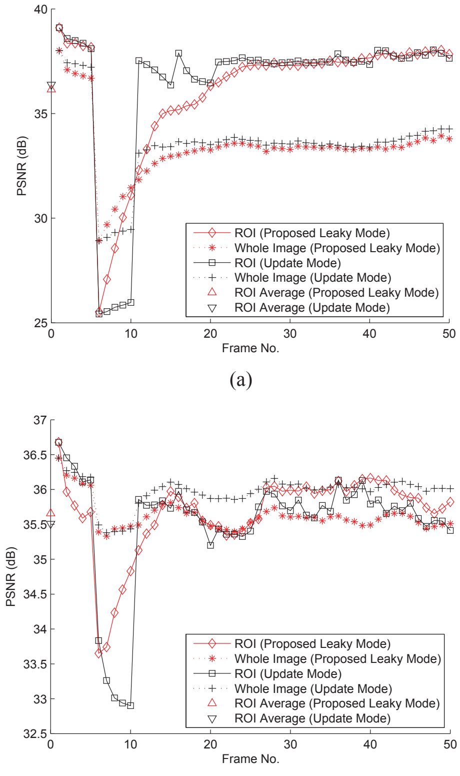
(a)

(b)

Fig. 3 Comparison of the subjective ROI quality for "Silent" when ROI slice of the first IDR frame is lost (a) update mode, (b) leaky mode.

3.2. Quality and Bitrate Property

Our scheme also has the effect of bitrate smoothness when constant image quality is desired. With nearly the same average bitrates produced in the update mode and in the leaky mode as before, size of the ROI slice and of the whole frame for the 49 P-frames (from the 2nd to the 50th frame) in each mode are shown in fig. 5. It can be seen that update mode makes the bitrate fluctuate drastically as the result of ROI-specific intra-update, while relatively smooth bitrate can be achieved with our proposed scheme.



(a)

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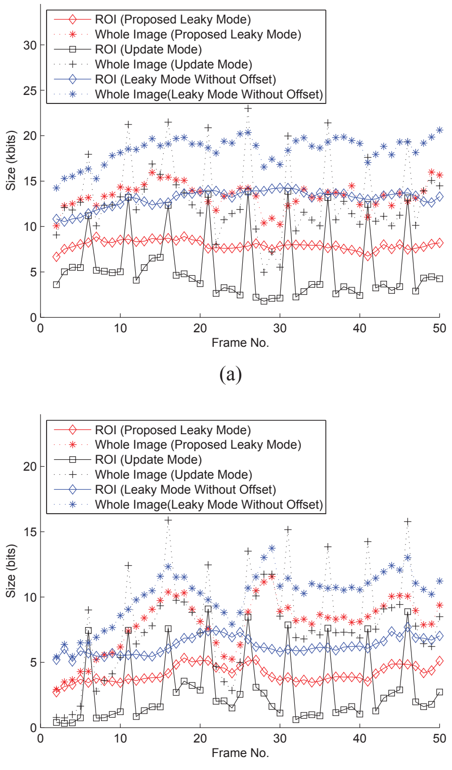
Fig. 4 Image quality of every frame when the 6th frame is lost (a) "Foreman", (b) "Silent".



(a)

(b)

Fig. 5 Bitrate fluctuation of the proposed scheme (a) "Foreman", (b) "Silent".

Considering smooth bitrate is always preferred by common transmission channels, our scheme is more suitable for practical video transmission with constant image quality.

With the same coding parameters, size of the ROI slice and of the whole frame for leaky prediction without offset is also shown in fig. 5. It's obvious that offset compensation is quite effective for improving coding efficiency.

4. CONCLUSION

In this paper, a ROI-specific leaky prediction scheme with offset compensation is proposed. In case of errors ROI-specific leaky prediction can make quality of ROI recover gently from immediate succeeding frames, which is usually preferred by human perception. In addition, our scheme is fully compatible with the existing H.264/AVC standard. Experimental results show that our scheme can improve image quality obviously compared to the commonly used ROI-specific intra-update method in case of errors. The byproduct of the proposed scheme is smoothness of bitrate, which is beneficial to transport related tools.

5. ACKNOWLEDGEMENT

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